Unit I: The Physics of Everyday Things

A. Introduction to Physics

The Nature of Science

The scientific worldview:

- The world is understandable; we assume the basic rules are the same everywhere.
- Scientific ideas are subject to change; new observations can challenge theories.
- Scientific knowledge is durable; modification of ideas, not outright rejection, is the norm.
- Science cannot provide complete answers to all questions; some things cannot be proved or disproved by their very nature.

Scientific inquiry:

- Science demands evidence.
- Science is a blend of logic and imagination; scientists do not work only with data and well developed theories. Inventing hypotheses or theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry, composing music, or designing skyscrapers.
- Science explains and predicts.
- Science is not authoritarian; nobody has special access to the truth.
- There are generally accepted ethical principles in the conduct of science.

Physics is the study of the world around us. More so, it is the study of matter and energy and how they interact. We attempt to explain the world through simple rules and mathematics.

Measurement and Analysis

Scientific Notation

Scientific notation is a quicker way of writing very large or very small number.

Rules for writing in scientific notation:

1. Write down all the significant numbers
2. Put a decimal after the first number. (the number will now be between 1-10)
3. Write "x 10"
4. Write the power corresponding to the number of places the decimal was (would have) been moved. (Moving right is negative, moving left is positive)
    - Count the number of digits between where the decimal was before and where it is now

Ex. Write 25000000000000 in scientific notation.

Ex. Write 0.0000000000300 in scientific notation.

Ex. Write 3.256×10^{5} in decimal notation.

Ex. Write 7.20×10^{-7} in decimal notation.

Arithmetic Operations with Scientific Notation

Look for and learn to use the EXP button on your calculator.

Units

Units identify what a specific number represents. For example, the number 42 can be used to represent 42 miles, 42 kilometers, 42 pounds, or 42 elephants. Without the units attached, the number is meaningless. The information is incomplete.

While there are many units systems, we use the SI units (Système International d'Unités).

The metric system (our version of SI) is designed to keep numbers small by converting to similar units by factors of 10.

Prefixes are added in front of a base unit to describe how many factors of 10 the unit has changed.

Base units of measurement are generally described by one letter:

- m – meter (length)
- s – second (time)
- g – gram (mass) *The base unit for mass is actually the kg (kilogram)
- L – litre (volume)

Derived units are combinations of base units. For example, speed is measured in m/s.

Metric Prefixes

See handout of prefixes.

Converting Units

Step Method:

Move the decimal the same number of distance between the two prefixes on the prefix chart.

Ex. Convert 45 Gm to km.

Ex. Convert 15 nm to km.

Ex. Convert 120 cm to nm.

Ex. Convert 23 km to cm.

Multiply by One:

- Multiply the measurement by a fraction that equals 1
- The fraction will contain the old unit and the new unit.
- The fraction must cancel out the old unit. (follow the rule that tops and bottoms cancel out)

Ex. Convert 24mm into m.

Ex. Convert 15.0 m/s into km/h.

The Sanity Test

After any calculation or problem, stop, take a deep breath, and look at your answer. Does your answer make sense?

Imagine you are calculating the number of people in a classroom. If the answer you got was 1 000 000 people, you would know it was wrong – that's an insane number of people to have in a classroom. That's all a sanity check is: is your answer insane or not?

In using the sanity test, it helps to know typical values of things.

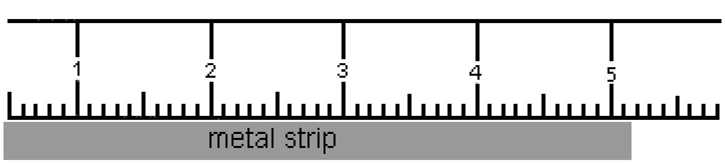
Accuracy vs. Precision

Accuracy is to the extent that a measurement agrees or compares with an accepted value or standard. A very accurate measure of boiling water might be 99.8°C, because it would be compared to the standard of 100°C.

The difference between an observed or measured value and a standard is known as error, and is sometimes written as a percentage.

The accuracy of a measuring instrument depends on how well it compares to an accepted standard, and it should be checked regularly. A known 500.0 g mass should show that same reading on a balance. If it doesn't, the balance should be re-calibrated.

If you were measuring a piece of metal with a ruler (like below), you would get a more exact measurement by using the side graduated in mm (the bottom of the ruler).

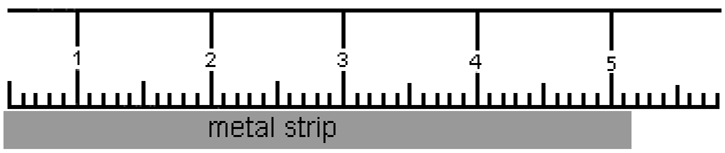


Precision is the degree of exactness that measurement can be reproduced. The precision of a measuring tool is limited by the graduations or divisions on its scale. In other words, you will have a more precise measurement of the metal strip above by using the graduations on the bottom of the ruler (mm) rather than the top (cm).

The precision of an instrument is indicated by the number of decimal places used. For example, 5.14 cm is more precise than 5.1 cm.

Significant Figures

When measuring, the precision is limited by the device - - the number of digits is also limited. Valid digits are called significant digits or significant figures. Significant digits consist of all digits known with a certainty plus the first digit that is uncertain.



The strip above is somewhere between 5.1 and 5.2 cm. We would state that the length is 5.14 cm. The last digit is an estimate (uncertain), but it is still valid and considered to be significant. There are 3 significant digits in this measurement; the 5 and 1 are known and the 4 is an estimate.

If the strip was dead on the 5.1 graduation, we should record this as 5.10 cm and we would have 3 significant digits.

Rules for Significant Figures

All non-zero digits in a measurement are considered significant. It's the zeros that sometime create problems.

1. Non-zero digits are always significant.
127.34 grams = 5 significant digits (s.d.)

2. All zeros between nonzero digits are significant.
1205 m = 4 s.d.

3. All final zeros to the right of a decimal point are significant.
21.50 grams = 4 s.d.

4. Zeros used only for spacing the decimal are not significant.
0.0025 = 2 s.d.

5. Zeros to the right of a whole number are ambiguous. A bar placed over a zero makes all numbers up to and including the barred zero, significant.

$50\bar{0}$ =3 s.d.

Sometimes, it is just assumed that all trailing zeroes are significant.

All digits written in scientific notation are significant.

Operations with Significant Digits

Adding and Subtracting:

The final answer cannot be more precise than the least precise measurement. In other words, the answer must have as few decimal places as the number with the fewest decimal places being added or subtracted.

Ex:

3.414 s + 10.02 s + 58.325 s + 0.000 98 s	1884 kg + 0.94 kg + 1.0 kg + 9.778 kg
2104.1 m - 463.09 ms	2.326 hr - 0.104 08 hr

Multiplying and Dividing:

Look at the number with the least amount of significant digits. Round the final answer to contain this many significant digits.

Ex.

10.19 cm × 0.013 cm	140.01 cm × 26.042 cm
80.23 m ÷ 2.4 s__	4.301 kg ÷ 1.9 cm^3 _

Multiple Operations:

When a series of calculations is performed, each interim value should not be rounded before carrying out the next calculation. The final answer should then be rounded to the same number of significant digits as contained in the quantity in *the original data* with the lowest number of significant digits.

For example, in calculating (1.23)(4.321) ÷ (3.45 − 3.21), three steps are required:

3.45 – 3.21 = 0.24

(1.123)(4.321) = 5.21483

5.31483 ÷ 0.24 = 22.145125

The answer should be rounded to 22.1 since 3 is the lowest number of significant digits in the original data. The interim values are not used in determining the number of significant digits in the final answer.

Graphing

See handout

Manipulating Equations

Since mathematics is a language of physics, it is important that you be able to rearrange formulas so that they are in a workable format. Basic algebra applies.

Sources

The Nature of Science
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